

## EFFECTS OF CONSOLIDATION ON THE ULTIMATE CAPACITY OF VERTICALLY LOADED ANCHORS

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### ABSTRACT

The results of a series of experimental tests on pull out capacity of a typical horizontal plate anchor under different sequential vertical loadings are presented in this paper. The loading comprises of a load applied under undrained conditions followed by consolidation of the soil under sustained loading and then undrained loading up to the failure of the foundation system. This sequential loading simulates the loads applied to the anchors of floating platforms during calm weather and during an ocean storm. For comparison, another anchor was also loaded up to failure under undrained conditions. The anchor is idealized as a circular plate embedded in a normally consolidated soft clay. The results of the experimental studies show that dissipation of pore pressures generated in the soil around vertically loaded anchors not only does not adversely affect the capacity of the anchors, but also increases their peak capacity.

**KEY WORDS:** Vertically loaded anchor; Soft clay; Consolidation; Ultimate capacity; Sequential loading; T-bar test.

### INTRODUCTION

Both the exploration and exploitation of hydrocarbons are heading more towards deeper waters. Tension leg, taut and semi-taut leg and semi-submersible platforms are among the options that are increasingly used in deep waters. With the greater depths there are greater needs for more robust anchoring systems to transfer predominantly tensile forces to the ocean floor. Vertically loaded anchors, or simply plate anchors, are among the few technologies currently used for this purpose in deep waters.

The last 20 years has seen a great increase in the capacity of drag embedment anchors, mostly due to improvements in design that have allowed a greater penetration in softer seabeds. This higher capacity has in turn allowed the extension of development into areas with much deeper water and more hostile environmental conditions. Vertically loaded anchors have the potential for reducing the cost of

anchoring system although this requires more confidence and experience in the design of the anchors.

Over the last 10 years or so an entirely new breed of drag embedment anchor has been developed. These anchors are configured at installation as drag embedment anchors. They are placed and installed in much the same way as the conventional drag anchors; the anchors can be penetrated to the required depth by drag forces or by direct penetration. However, after penetrating to the required depth the new anchors can be reconfigured so that the anchor pulling line forms a right angle to the fluke, thus increasing the available uplift capacity by a factor of about 2. These anchors have different innovative designs to satisfy the needs for load resistance as well as convenient installation procedure. Unlike the conventional drag anchors, the capacity of the new anchors is not dependent on the direction of pull so that even direct vertical loading can be sustained.

Anchors are usually subjected to a permanent tensile loading, which is a fraction of the maximum undrained capacity of the anchor, and is required for the stability of the platform. They are also subjected to temporary fluctuating loadings applied due to storms and surface or deep currents. The permanent load applied to anchors in shallow water is significantly less than storm loading, unlike in most deep water environments where anchors often support higher levels of sustained tensile loads of mooring system. The sustained load is usually applied in a relatively short period of time and then remains approximately constant with time. This will result in dissipation of the initial excess pore pressures and consolidation of the soil around the anchor so that when the storm loading is applied it might be expected that the response to loading differs from that for a single first time loading.

Drainage is one of the main effects of long term loading on anchor foundations. The suctions and positive excess pore pressures generated under and above anchors during the first time undrained loading will dissipate with time. This would result in strain softening and reduction of soil shearing strength under the anchor, while the